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A virtual globe tool for searching and visualizing geo-referenced media resources in social networks

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Abstract The current collaborative context and resource sharing that drives Web 2.0 is gaining importance within academia and industry, which is stimulating the development of new techniques for content retrieval, sharing and analysis over user-generated media content. This poses new challenges and research opportunities in spatial-based discovery media resources over varied sources, since location context is being increasingly supported in most of these social networks and services. In this paper, we present a virtual globe tool for searching and visualizing geo-referenced media resources. Our approach is based on the integration of search technologies, description languages for annotating collections of geo-referenced media resources and visualization techniques. The combination of these techniques is materialized in a virtual globe-based tool to facilitate searching and presentation of geo-referenced media resources available in different social networks.

Keywords User-generated content retrieval · Social networks · Geo-referenced media resources · Virtual globes · OpenSearch · KML · MIMEXT

1 Introduction

Users are dominating the Web 2.0 vision. They have rapidly become providers of content in a new age of social multimedia identified by the increasing flow of web-based sharing and

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community services [7]. As content is now mostly user-generated, location has become the predominant context in annotating any type of resources, leading to huge amounts of geo-referenced information in practically any domain [16].

Therefore, the geo-location of any kind of resource is acquiring a fundamental role in a wide range of applications. Examples of this trend are geo-tagged pictures: users are increasingly annotating their photographs, either manually or automatically via GPS-aware devices, to position them geographically in virtual globes or map visualization services. Nevertheless, geo-tagged images represent only one type of resource available in the collaborative environment empowered by social networks and Web 2.0 services. Essentially, users are increasingly demanding the possibility of sharing other types of geo-referenced media resources, such as text files, videos, audio and tweets, through collaborative geo-spatial applications like virtual globes [7]. In this sense, virtual globes are becoming the "fusion platform" of choice that allows the combination of media content coming from disparate social networks, sources, and services to cover a wide range of user needs [4].

User-generated content is growing exponentially which allows people to share content at a great scale [6]. However, this also poses new research challenges in spatial-based discovery of on-line multimedia content [40]. Rather than using specific search interfaces for any sort of social network, users would desire a common search strategy that spans uniformly over disparate social networks. Otherwise, users need to know each specific search API (Application Programming Interface) of the targeted social networks and services used. This implies that client applications increase in complexity and become less scalable, since searching over a new social service requires the understanding of its search API. To overcome this issue, we provide a uniform, homogeneous search interface to augment the visibility of user-generated content over different social networks. The same search interface is used regardless of the nature of the social networks and services queried. Furthermore, the contributions of this paper are three-fold:

- A simple but powerful enough tool to search media resources in social services and networks.
- A KML (Keyhole Markup Language) extension to annotate collections of geo-referenced media resources.
- A virtual globe application to enable the searching, visualization, and reproduction of geo-referenced media content.

In this paper we underline the role of virtual globes as data fusion tools for experts and the general public alike. With this goal in mind, the first contribution is a uniform spatial-based query mechanism integrated in a virtual globe tool that allows us to search and collect media resources from diverse Web 2.0 sources. This provides users with a mechanism to easily search media data not only based on keywords or tags but also considering geospatial constraints like a given geographical area. The result set in terms of collections of geo-referenced media resources is then codified in a proposed KML [45] extension focused particularly on geographic and media type annotations. MIMEXT (MIME extension) is thus the second contribution, a KML extension that exploits the power of KML to contain any type of geo-referenced media content. The third contribution is realized by the VisioMIMEXT application which extends a virtual globe tool to comprise together the searching, visualization, and reproduction of these collections of geo-referenced media resources over a virtual globe.

VisioMIMEXT aims to improve searching and visualizing of user-centric media content, although our assumption here is that online media content is already somehow geo-tagged, either manually or by automatic processes. Recent and prominent research works are devoted to alleviate the issue of geo-tagging media content manually [32, 37], yet few works are still centred on searching and retrieving such geo-tagged media content.

The rest of the paper is organized as follows. We overview related work in the areas of geospatial-based retrieval of multimedia, annotation, and virtual globes in Section 2. Section 3 introduces the main points of our approach. The following three sections are centred on each of the three contributions. Section 4 describes the search mechanism of geo-referenced media resources, Section 5 is focused on the proposed MIMEXT extension to annotate collections of geo-referenced media resources, and Section 6 describes in detail the Visio-MIMEXT application accompanied with examples. Section 7 concludes the paper with some final considerations and future research lines.

2 Related work

The proposed system is related to different research fields including retrieval, tagging, and visualization of geo-referenced media resources. In the following section we review the most relevant work and techniques in these fields.

2.1 Spatial-based search engines

Search engines are information retrieval systems aimed at helping users in discovering information on repositories, networks, and services. The topic of search engines applied to user-generated media content is gaining much attention as result of the proliferation of social networks and Web 2.0 services. In such a context, Schreer et al. [50] proposed a retrieval engine for large video repositories, where video media content is split in semantic units to enable indexing, search and browsing.

Despite these recent works, attempts in providing spatial-based search engines over media content are relatively scarce [53]. One of the reasons may be found in the diversity and heterogeneity of media content. Some exceptions, however, prove that spatial-based query engines combined with geo-visualization tools leads to comprehensive and useful applications. Alkemis [3], for instance mixes up media content and other domain information such as traffic and weather to offer customized location based services [7].

Walsh [57] pointed out the need to pay attention to search and discovery interfaces widely spread in other information communities different from the established catalogues services in the geographic domain [41]. In this sense, our approach is to put in practice this idea and apply a search mechanism, which is not specific to multimedia and geospatial domains, to allow users spatial-based queries over different social networks and services in a homogeneous way.

2.2 Annotation techniques

In previous works we discussed annotation techniques for geo-referencing media resources [1]. Annotation techniques may be organized into two categories: internal and external. The first category aims towards adding some internal annotations in the very resource. The internal modification of a file for adding metadata and geo-referenced annotations is an extremely format-dependent, intrusive approach. Basically, most of these approaches are based on the addition of geo-referenced information as image metadata in terms of header fields. Examples are Adobe Extensible Metadata Platform (XMP) [2], International Press Telecommunications Council (IPTC) [30], and Exchangeable Image File Format (EXIF) [35].

In contrast to the internal annotation oriented solutions, the second category consists of encapsulating both the resource and its metadata as a unit, either on a physical or logical level. Most techniques for external annotation are based on geo-referencing resources from external files. The most prominent example is SMIL (Synchronized Multimedia Integration Language) [9], where the resource remains intact, but it loses the notion of physical unity since data and metadata are in separate files, making it difficult to manage and share. New formats emerged to enhance external annotation solutions with the ability to encapsulate (metadata) annotation files and data files themselves into one single file, leading to both logically and physically compact resources. This is the case of MEF (Metadata Exchange Format) [24] and KML [45] formats.

We argued that external annotation techniques combined with encapsulation present several advantages [1]. Data and metadata forms a single unit and the size of the metadata content is not a restriction as in the case of internal annotation techniques. These techniques also are flexible enough to accommodate new data formats since they are not intrusive, that is, they do not alter the original files. Then, we selected KML format in our approach because its characteristics meet our requirements as will be explained in the following.

Recently adopted as OGC (Open Geospatial Consortium) [46] standard, KML has been broadly used to encode disparate web resources [5, 14]. Its popularity probably stems from its simplicity, inherent visualization and annotation capabilities [60], which allow KML to be widely supported by the most common geospatial tools and web mapping services.

KML provides some built-in mechanisms to geo-reference media resources by attaching visualization details and metadata annotations to them. For visualization, KML offers a rich set of visualization options either in 2D and 3D environments [11] attached to the set of basic primitive geometries such as <Point> and <Polygon>. However, there are some conceptual and technical issues to be considered when addressing the addition of metadata annotations to media resources.

Firstly, KML supports the addition of different kinds of HTML-encoded resources within the KML <Description> tag. This is the case of image or video resources (e.g. Adobe Flash) that are usually geo-referenced using the KML <Placemark> tag along with a simple geometry like <Point>. This simple geometry is valid in most of the cases but it turns out be insufficient in other settings like audio tracks describing a route (lineal geometry) and terrain parcel (polygon) with an associated PDF document with cadastral information. Basically, KML supports the geo-referencing capability of resources that can be embedded within the KML <Description> tag, which in reality is limited to a few media types such as images and videos. Secondly, the methods for embedding resources inside other KML tags were not originally designed for accommodating any type of media resource; therefore they potentially omit most of the media types available in social networks.

To overcome these limitations, KML defines a set of rules to extend itself by adding more functionality [45]. Based on the KML extensibility rules, section 5 will describe a new KML extension which allows us to geo-reference a wide range of mime types of resources that cannot be effectively annotated with the KML built-in mechanisms. Our approach extends KML format by combining external annotation and encapsulation techniques along with compression to ease the sharing of collections of geo-referenced media resources.

2.3 Geo-visualization

Geospatial data visualization has traditionally been an important aspect in the development of geospatial applications. Huang et al. [29] introduced Virtual Reality Modelling Language

[56] as a way to integrate Geographic Information Systems (GIS) technologies and Virtual Reality techniques for spatial data visualization, analysis and exploration in urban settings. Zhu et al. [68] introduced 3D GIS in a city environment that enabled users to explore the environmental and cultural information about the city. With the advent of Web technologies, Hobona et al. [28] explored the use of Java 3D technologies to support Web-based 3D geospatial visualization of vector and raster data. Zhang et al. [67] developed an Internet-based virtual 3D environment as a collaborative platform for publishing, sharing and analyzing geospatial information.

As technology has progressed, virtual globe-based 3D technology has recently become part of the GIS landscape, leading to more intuitive, online visualization techniques [10, 13]. Compared to previous 3D geo-visualization applications [28, 29, 67, 68], the most important feature of virtual globes is the seamless visualization in both the spatial and zooming dimensions. Firstly, diverse spatial dimensions (geographical features, roads, buildings, etc.) enable users to visualize the Earth as a whole and leap from one viewpoint to another. Secondly, improvements in the zooming techniques enable users to smoothly zoom in and out with continuous resolution [64].

Sheppard and Cizek [51] have recently remarked the potential benefits of virtual globe systems. They highlight that virtual globes not only provide a 3D model of the Earth with satellite imagery, but also offer users rapid access to massive amounts of geospatial information, and high levels of satisfaction because of the ability to visualize and navigate through their own geospatial data. This links with the increasing amount and variety of user-generated media content available from social networks, and the fact that such resources may be potentially geo-referenced [39] and thus explored via virtual globe applications.

As also noted in [51], virtual globes are easy-to-use applications addressed to both experts and non-experts. This is demonstrable by the increasing developments on top of virtual globe applications (e.g. Google Earth [26] and NASA's World Wind [61, 62]) in a great variety of scientific scenarios such as environmental modelling [11, 52, 65] as well as in non-expert geographic mashup applications [48].

3 The approach

As mentioned earlier, three goals drive our research, namely: a simple but powerful spatial-based query system over social networks and Web 2.0 services; a description language to group together media resources; and the ability to both visualize and reproduce the retrieved collection of geo-referenced media resources over the virtual globe. Given this context, our approach has some implications in the common activities (searching, annotation and visualization) carried out by users when they are interacting with social networks (Fig. 1, top). In this section we elaborate on how our solution helps users to easily perform these activities, whereas design and implementation aspects will be treated in the following sections.

The ease of media content production and publishing makes vast amounts of user-generated content available. Web users are either equipped with GPS-aware devices or manually capture the current position in term of annotations [39]. As a result, social networks are being transformed into immense online repositories with geo-referenced media content ready to be shared, accessed and searched by people. When users search for media resources, they first search for resources of their interest by typing some keywords or tags. As the returned resources are mostly geo-referenced, users may visualize them on web mapping viewers, multimedia mashups or virtual globe applications.

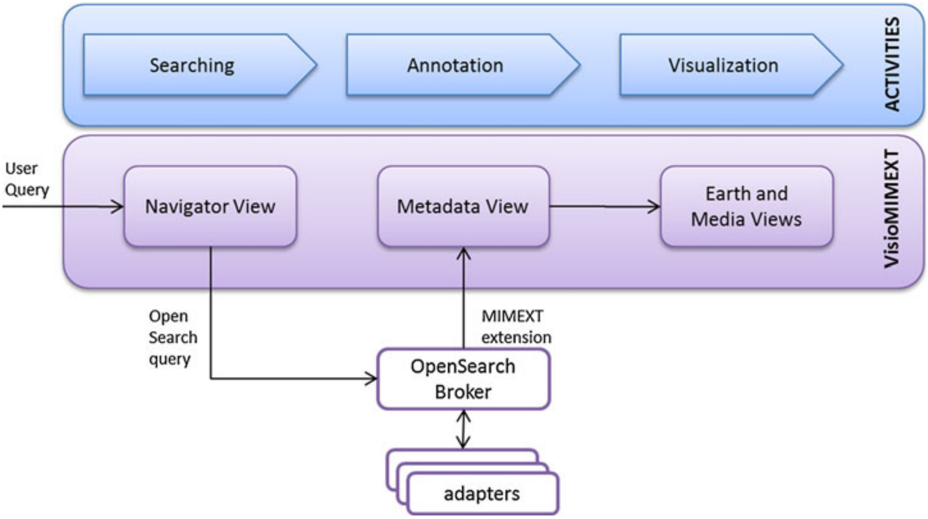

Fig. 1 Relationship between the user activities (top) and the technologies and components contained in the VisioMIMEXT application (bottom)

The activity flow sketched in Fig. 1 (top) reflects to some extent how users interact with social networks: they first annotate and upload content, search for other users' content ("Searching" in Fig. 1) to commonly visualize it or by sharing it with other users [6]. Then search results may be automatically enriched with additional annotations ("Annotation" in Fig. 1) for visualization and presentation purposes ("Visualization" in Fig. 1). This is precisely the meaning of the annotation activity considered throughout this paper, rather than adding tags from scratch when users upload and publish media content into social networks.

These activities, which may be quite logical and commonplace, still present serious challenges on a technical level. For instance, Web 2.0 services normally provide their formats and tags for geo-referencing but, most importantly, expose their specific data discovery and access interfaces (API) to client applications. Indeed, it is hard to find similar ways to perform common functionality among different discovery service interfaces. This implies that the process of searching over multiple services becomes a tedious task because of the variety of response formats and ways to query the underlying services.

Many tools such as media players and photo-sharing community services allow users to visualize media content. However, eager users are increasingly demanding new capacities such as geographically positioning any media resource found in social networks into a virtual globe and reproducing its content at the same time. Furthermore, new social media applications require an integrated approach that mixes technologies and techniques from disparate fields like multimedia, information retrieval, resource annotation, and geographic information systems.

Figure 1 (bottom) depicts the interaction among the components of the VisioMIMEXT application according to the three basic user activities described earlier. In the following three sections we describe how the set of techniques (Sect. 2) and components are mixed to form the core of the VisioMIMEXT application. Specifically, the "Searching" activity (Fig. 1 top) is treated in Sect. 4 where we introduce a common spatial-based search mechanism of geo-referenced media resources. The Navigation View (Fig. 1 bottom) contains a web-based interface to support such a searching mechanism and utilizes internally the OpenSearch Broker and the set of adapters. The "Annotation" activity (Fig. 1 top) is discussed on Sect. 5 where collections of searching results are annotated in an enhanced KML-based format (MIMEXT extension) designed for geo-referenced media resources. Finally, the Visualization" activity (Fig. 1 top) is presented in Sect. 6 where the VisioMIMEXT application is able to visualize the collection of geo-referenced media resources on a virtual globe. In this case, the Metadata, Earth and Media Views (Fig. 1 bottom) components allow users to interpret, visualize, and reproduce geo-referenced media resources over the virtual globe.

4 Searching of geo-referenced media resources

Users have a growing interest in sharing heterogeneous, media content in social networks. This media content is uploaded into different Web 2.0 applications and services depending on its nature. For instance, geo-tagged photographs can be shared through Flickr [17], while short text messages are shared via Twitter [55]. Nevertheless, despite the popularity of social networks and social media services, there have not been many approaches that allow users to search for media content regardless of the nature of the underlying social networks and services [40]. Indeed, most of these crowd-sourced online services have developed their own functional API, and use specific encodings formats and schemas. Browsing and accessing such services to gain access to different varied media resources requires comprehensive knowledge of every discovery service API. This constitutes a technical barrier for the discovery of geo-referenced media content over several sources.

To overcome this problem our approach relies on the belief that users expect, and in reality are used to, search interfaces based on minimal input. Essentially, advanced query might be desirable and even available but simple query capacities are mostly preferred by users to search for the right content from a large number of possibilities. To illustrate the benefits of minimal search interfaces, the "custom search" textbox-based tool available in most of web browsers is a simple but interesting working discovery service that exemplifies the pragmatism and simplicity of Web 2.0 services [7]. Web users can easily customize this tool by choosing from a collection of on-line data repositories and services such as online shops, dictionaries, and general-purpose search engines. Independently of the data repository or service used, the query interface is always the same: users type in a term and obtain the list of results from Google, Amazon or Wikipedia.

This example represents the most widespread use case of the OpenSearch specification [12]. OpenSearch has rapidly become a successful query mechanism over thousands of websites, services and repositories which are increasingly adapting it to expose their searching interfaces in a standard and simple manner. In this section we firstly describe the OpenSearch basic interface and the Geo extension, followed by a discussion on how we have adopted OpenSearch as a common query interface that allows us to perform spatial queries over social networks and services.

4.1 Keyword-based query pattern

OpenSearch provides minimal search and retrieval capabilities that any repository and service should support. OpenSearch describes a basic search pattern that fits nicely into the minimal search interfaces that identified most Web 2.0 services. An OpenSearch-enabled service exposes an OpenSearch interface to inform client applications, such as the "custom search" tool described earlier, as well as how to issue simple HTTP GET queries expanded with specific query parameters. As a result, responses are often encoded in lightweight data formats such as GeoRSS [25], Atom [42], or KML [45].

The OpenSearch search interface has only one mandatory query parameter called "searchTerms" and allows client applications to retrieve resources that are related to one or more keywords or search terms. Other query parameters like those supporting response pagination ("count", "startIndex", "startPage") are optional. On the server side, the OpenSearch-aware service performs a text-based search over the resource repository and typically considers the following metadata descriptors for each target resource: title, author, description, and user-defined tags. It is worthwhile noting that the list of target metadata descriptors depends on the specific service. For instance, Twitter, Flickr and YouTube [66] may share some descriptors but surely others are different.

4.2 Spatial-based query pattern

Although the keyword-based search pattern works well in many settings, advanced search criteria should be put in place via extensions or specialized profiles. In the OpenSearch community, specific search profiles are described by extending the base OpenSearch capabilities (Sect. 4.1). Among the extensions suggested,[1] the Geo extension [54] defines a list of query parameters to enable geographic filtering. Spatial-based queries are then supported through the proper combination of OpenSearch and its Geo extension search interface (OpenSearch-Geo).

The OpenSearch-Geo is built upon the basic OpenSearch specification, so all mandatory and optional query parameters previously mentioned are also available. Apart from these base parameters, the OpenSearch-Geo extension defines some specific, optional query parameters. The "box" parameter filters results from a rectangular area. The "lat", "lon" and "radius" parameter filters result from a circular area around a point. The "geometry" parameter defines a geographic filter by means of an arbitrary geometry. The "name" parameter allows filtering by place name.

Although OpenSearch and OpenSearch-Geo specifications do not specify any mandatory response format (but both recommend supporting at least the Atom format [42]), functional responses should attach geographic descriptions to each result item so that client applications can handle geo-referenced media resources. Common geographic response formats used in current OpenSearch-geo implementations are driven by two approaches. The first one consists of using existing non geo-specific formats, such as HTML, JSON (Java Script Object Notation) [34] and Atom [42]. In this case, these formats are enriched with geographic annotations, such as the geo microformat [21] in HTML and the GeoRSS extension in RSS (Really Simple Syndications) and Atom formats. The second approach is to use native geographic-oriented formats such as KML. To provide a balanced approach, our decision was to support Atom for keyword-based queries, and Atom extended with GeoRSS and KML/MIMEXT KML for spatial-based queries, as described in the following section.

4.3 OpenSearch Broker

After reviewing the main characteristics of the OpenSearch interface, the focus of this section is to describe how users can homogenously search over different social networks through the OpenSearch Broker component.

[1] http://www.opensearch.org/Specifications/OpenSearch/Extensions

A potential collection of social media services with geo-referencing capabilities have been analyzed, and only those that support geospatial filtering functionality through their public API have been selected as target repositories [18]. The selected services are Twitter (near real time short text messages), Flickr (photographs), Geonames (place names) [23], Wikipedia (encyclopaedic descriptions of place names) [58], YouTube (video) [66] and Open Street Maps (tagged vector geometries) [47].

In order to provide a common OpenSearch-based query interface over these services, we have developed a set of specific adapters for each service to mediate between the OpenSearch interfaces and the particular service discovery interfaces. The set of adapters together with the specific social networks and services are shown in Fig. 2. The self-developed components (Fig. 2, shaded boxes) play a mediating role between service-specific APIs (Fig. 2, right white boxes) and potential OpenSearch-enabled clients. For instance a client application may search over any number of social media services using the same simple search pattern.

For instance, the Flickr adapter (Fig. 2) takes in user queries similar to the following OpenSearch-styled URI:

http://geoportal.dlsi.uji.es/OpenSearch/services/flickr/search.php?q={searchTerms}&per_page={count?}&page={startPage}&format={responseFormat}

This adapter injects the query parameters into the specific Flickr API discovery methods and carries out the query. Optional query parameters may be encoded in the URL itself for results pagination, language selection, and character encoding. Each adapter advertises the set of accepted query parameters and supported response formats through its OpenSearch service description document [12]. For instance, a given web page contains a special "discovery service" HTML tag that points to the corresponding OpenSearch description document. As this discovery tag is understood by most modern browsers, these may activate the "add search engine" option of the "custom search" tool mentioned earlier. This easy mechanism allows client applications to understand the discovery interfaces supported by services and how to build valid OpenSearch-styled queries.

The OpenSearch Broker component (Fig. 1, bottom) acts as a single entry-point to the set of adapters in Fig. 3 for two reasons. On the one hand, the OpenSearch Broker allows users to control the search procedure by selectively activating the adapter that is used in function

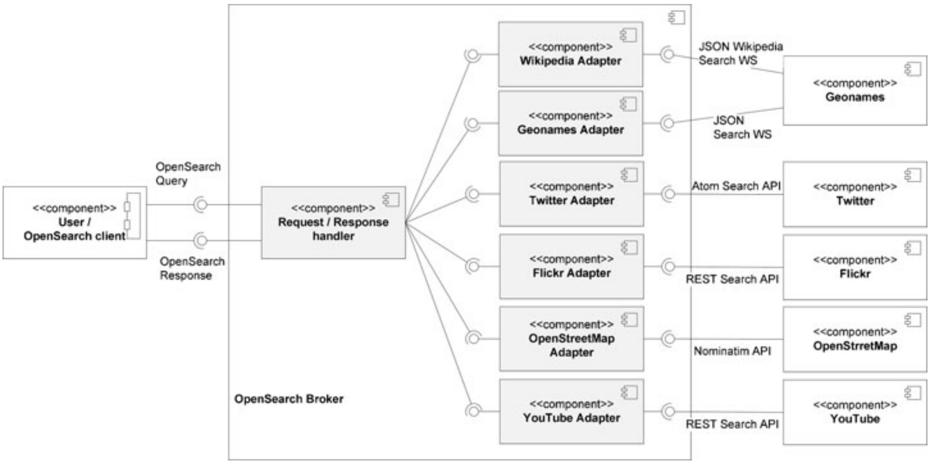

Fig. 2 OpenSearch adapters developed for different social media services

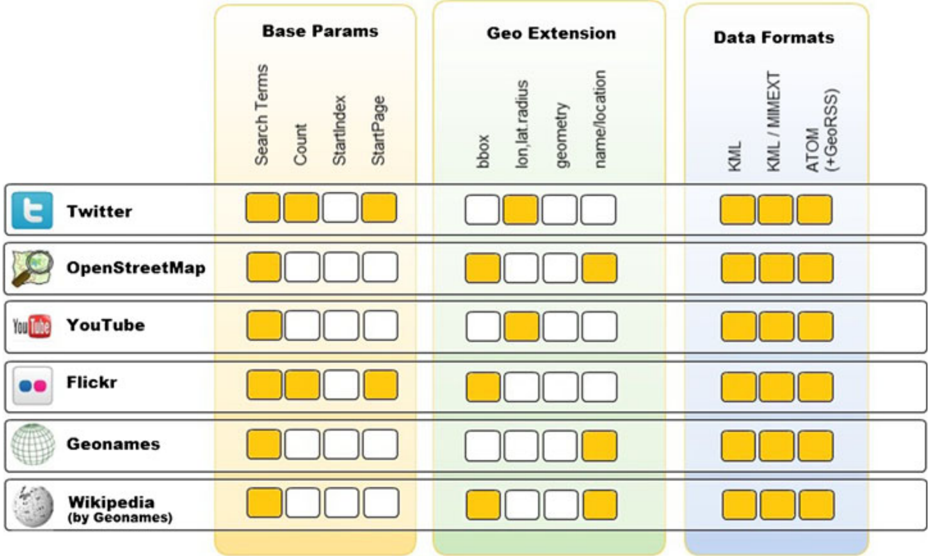

Fig. 3 Search filters and response formats supported. Note that the column for KML format is also valid for the proposed KML extension (MIMEXT)

to the query criteria. Users, via the OpenSearch client contained in the VisioMIMEXT application (see Sect. 6), can select one or various adapters or even the whole set. In this sense, the OpenSearch client within VisioMIMEXT plays the same role as the previous example of the "custom search" tool within browsers.

On the other hand, since these social networks and media services offer specific discovery interfaces, they also provide different response formats. For instance, the Flickr adapter collects the query results in Atom format while the Geonames adapter does so in JSON format. The OpenSearch Broker thus collects and merges all search results into the same format (Atom, KML or MIMEXT) to be finally forwarded to client applications. The "broker-adapters" configuration is flexible enough because new adapters may be added without altering the broker's discovery interface from the client perspective. In doing so, clients and adapters are independent, loosely coupled components where each one evolves separately, enhancing the system scalability as a whole [43].

Although some social media services expose discovery interfaces through the Open-Search specification (Flickr, Wikipedia), these do not offer the OpenSearch-Geo search interface. The set of developed adapters and the OpenSearch Broker component support spatial queries over those services that natively support, to some extent, geographic search capabilities through their own API. For instance, users can search for media resources restricted to a given area of interest represented as a rectangular geometry (bounding box).

Figure 3 shows the specific capabilities of each adapter in terms of the OpenSearch and OpenSearch-Geo features, along with the response formats supported. These capabilities are limited by the functionality offered natively by each specific API. For example, some services allow filtering by bounding box and others by centre and radius. In all cases, KML and Atom extended with GeoRSS are provided as standard geographic formats in the response. In our case, KML responses incorporate the MIMEXT extension, which specifically manages collections of geo-referenced media resources, as described in the next section.

In terms of search accuracy and performance, the OpenSearch Broker depends completely on the accuracy supported by the social networks and services queried. For instance, few tweets are actually geo-referenced and their localization is determined by the user profile. In this sense, if a Twitter user does provide her location, her tweets cannot be searched with the spatial-based criteria proposed. In addition, the nature of each service leads to different constraints and requirements in terms of discovery. For instance, Flickr resources can be queried over time while Twitter resources are only discoverable during a narrow time window. Indeed, these open issues pose new challenges in the field of social mining [49].

5 Enriching collections of geo-referenced multimedia resources

As commented earlier, the OpenSearch Broker component merges all the result sets into a collection of geo-referenced media resources. This collection is serialized into the KML-based extension language. In this section, we describe such a KML extension (MIMEXT) which is meant for grouping and visualizing different media resources on virtual globe applications like VisioMIMEXT.

5.1 MIMEXT KML extension

The release of HTML5 introduces new multimedia tags to natively cover a great deal of media content. We take a similar approach in extending KML to facilitate the integration of collections of geo-referenced multimedia resources that KML does not yet support. The proposed KML extension called MIMEXT (MIME Extension) enhances KML in two aspects: better geo-referenced mechanism and support for a large variety of media types via annotation.

The extension and restriction for specific purposes of the standard OGC KML scheme is possible via Application Profiles [45]. An Application Profile (AP) must adhere to certain constraints, which ensures that the new tags are correctly derived from the base KML elements. The proposed MIMEXT AP (MIMEXT for short) is built by inheritance, that is, the new elements and tags are derived from KML core abstract base types.

MIMEXT consists of new elements for geo-referencing media content and annotating the MIME type of resources. Regarding the first group, elements to accommodate geo-referencing capabilities, they derive directly from the KML <Geometry> tag. This effectively permits associating this geometry with any media resources that are not currently supported by the KML standard.

Regarding the second group, additions made to register MIME types, the proposed elements deal with the MIME type of a given media resource and its file type extension. This information may be useful, not only for the end user but also for underlying client applications capable of offering a direct visualization of these resources. As we see in section 6, the VisioMIMEXT application is able to directly visualize such resources over a virtual globe or by delegating its control to the corresponding application associated to the file type or extension.

The resource type description should follow the MIME type specifications [8, 19, 20]. An extensive list of MIME types is defined,[2] each one specifying their file type, subtype and extension. This has been taken as base for our approach in order to provide information about the resource in a way that is as standardized as possible.

[2] http://www.iana.org/assignments/media-types/

5.2 MIMEXT structure

XML files have a well-defined structure, particularly with regard to nested structures and the syntax of elements, attributes and types. Figure 4 shows all the elements used to build up this new extension and the hierarchy of elements.

The MIMEXT <Resource> element is derived directly from the KML <Feature> abstract element and, by inheritance, it contains the same elements that <Feature> has. Apart from the KML elements inherited, the MIMEXT <Resource> element includes the following three specific tags (Fig. 4, right). The KML <AbstractGeometryGroup> tag (denoted as Geometry in Fig. 4) determines the geo-referencing information associated with the resource (<Resource>). This information can be of any type of geometry supported in KML (<Point>, <LineString>, <LinearRing>, <Polygon>, <Multigeometry> or <Model>). The KML <Link> tag permits specifying the location (URI) for a given resource. Currently we support pointing to local and remote resources. The <Link> tag becomes essential when loading content from remote geospatial services like Web Mapping Services [44] or other social services like Flickr images. The MIMEXT <MimeInfo> tag facilitates the annotation of the MIME type for any given resource by indicating its MIME type, subtype and file extension using the MIMEXT <MimeType>, <MimeSubType> and <MimeFileExtension> tags respectively. This information intends to be processed and used by applications such as virtual globes to visualize or work conveniently with the resources. Finally, we can improve resource descriptions by incorporating more metadata in other KML <Feature> derived elements. For example, we could incorporate inside the KML <Description> tag new metadata element tags based on the characteristics of the resource or even a complete metadata record compliant with ISO 19115 [31] within the KML <ExtendedData> tag. A snippet example of a MIMEXT description is shown in Fig. 5.

Finally, KML also supports encapsulation by using compressed KMZ files. A KMZ file is just a zipped file containing a KML file and a folder with resources referenced in this KML. In this sense, KMZ represents a simple but powerful solution for the encapsulation into one single file of any type of resource along with its geospatial location and other descriptive information embedded within a KML file ,and hence, in the MIMEXT extension. This approach offers the same benefits listed for KML plus a simple way of combining both the resource and its associated information.

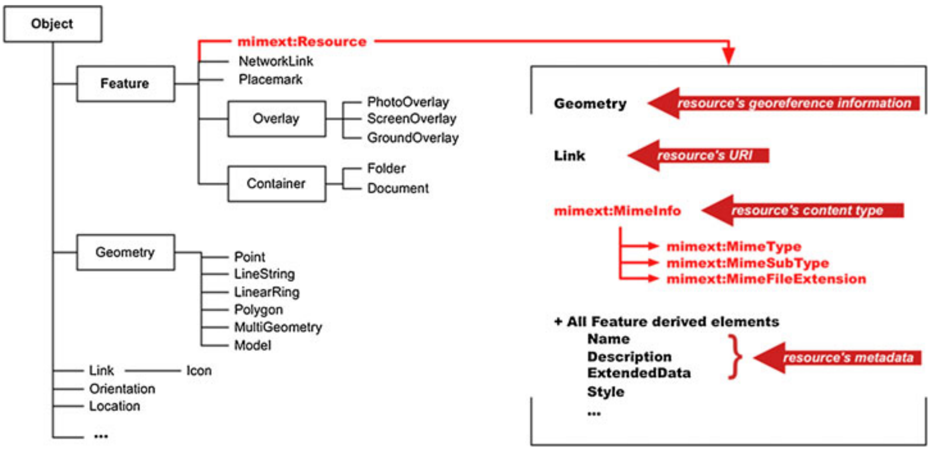

Fig. 4 The hierarchy and relationship between KML elements (*black*) and MIMEXT elements (*red*)

```
<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://www.opengis.net/kml/2.2"
  xmlns:mimext="http://www.geoinfo.uji.es/kml/ext/2.2">
<mimext:Resource>
<name>Audio Resource</name>
  <description>This is a test for audio resources</description>
  <Point>
    <coordinates>26.8694,37.2545,0</coordinates>
  </Point>
  <Link>
    <href>resources/audio_file.wav</href>
  </Link>
  <mimext:MimeInfo>
    <mimext:MimeType>audio</mimext:MimeType>
    <mimext:MimeSubType>wav</mimext:MiMeSubType>
    <mimext:MimeFileExtension>wav</mimext:MimeFileExtension>
  </mimext:MimeInfo>
</mimext:Resource>
</kml>
```

Fig. 5 Example of a simple MIMEXT elements (*red*) describing a single geo-referenced audio resource

6 VisioMIMEXT

VisioMIMEXT is a desktop application to enable the visualization and reproduction of geo-referenced media content in a virtual globe. It has been implemented as a proof of concept tool that integrates the proposed OpenSearch technology and the MIMEXT format for resources annotation, along with other components to enable searching and displaying different types of geo-referenced resources. VisioMIMEXT and all its components have been developed entirely in Java using the Eclipse RCP (Rich Client Platform) framework [15]. VisioMIMEXT user interface has the Eclipse look because most of the graphical interface has been delegated to Eclipse classes. More details about the components implementation and about the tool functionality will be provided in the following subsections.

Figure 6 shows a simplified architecture of the VisioMIMEXT and its main components. The main user activities in the left column (see also Fig. 1, top) are connected to the components (two most-right columns) for searching and visualizing MIMEXT-encoded collections of geo-referenced media resources in a virtual globe. While Fig. 1 shows the interaction flow of the whole system at high level, Fig. 6 is more detailed, specific and centred in the application.

6.1 Navigator view

The Navigator View is aimed to facilitate user navigation through the virtual globe implemented by the Earth View and spatial-based queries. As the Navigator View is concerned with user interface aspects, the Search Manager module comprises all the functional components: geo-coding, layer management and OpenSearch client (Fig. 6).

The geo-coding component allows users to “fly to” a certain position on the globe by computing on-the-fly the geographical coordinates given to a place’s name or address (*Fly to* frame in Fig. 7). It acts as a client since the actual geo-codification process is operated by the Yahoo API for geo-coding web service [22].

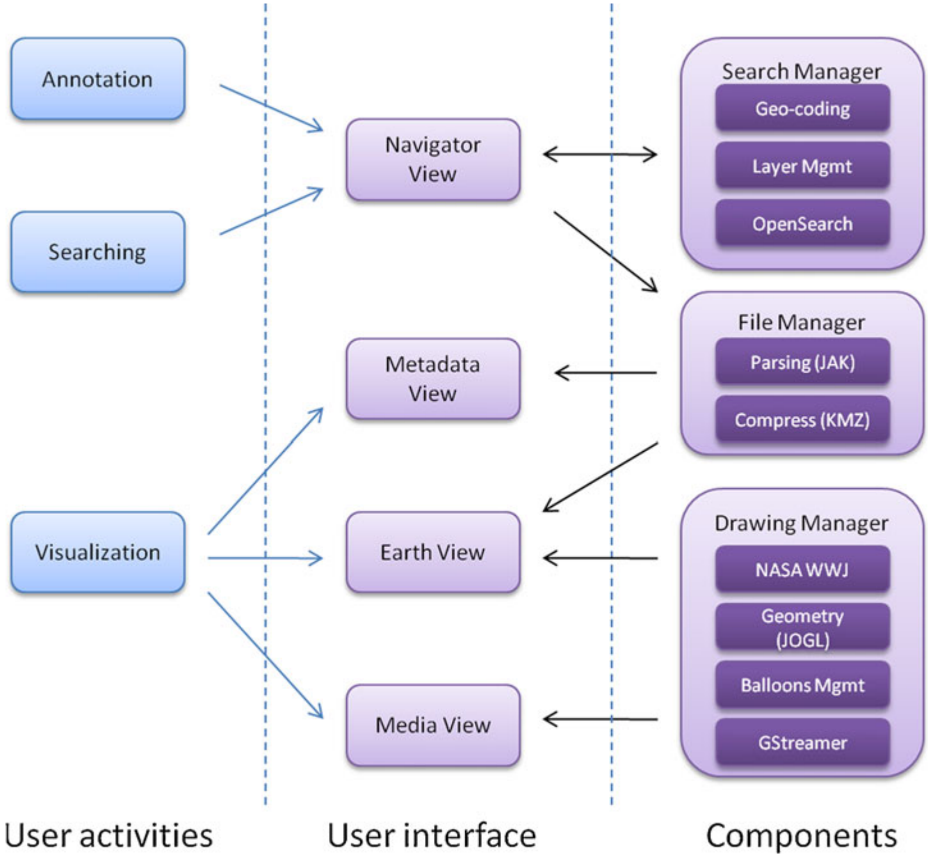

Fig. 6 The VisioMIMEXT architecture combines user activities, VisioMIMEXT user interfaces (views), and internal components

The concept of overlapped layers on the virtual globe is managed by the Layer Management (*Layers* frame in Fig. 7), which enables and disables any viewable layer in the list box. It is worth noting that search results are cached and treated as a layer. One may disable a searching layer and enable it further without carrying out the query again. For instance, the *OpenSearch (hotels)* layer listed in Fig. 7 represents the resulting list of geo-referenced media content annotated with the geo-tag *hotels* and located around the Madrid area.

The OpenSearch component allows users to search for media resources through the OpenSearch protocol and its Geo extension (Sect. 4). As commented earlier, queries can be based on keywords, on a geographic area of interest (bounding box), or both. Keyword-based queries are typed directly by the user in the *OpenSearch* frame (Fig. 7 in detail and left side of Fig. 8), while the area of interest is automatically set in the query as the active view of the virtual globe (Fig. 8, right). For instance, when zooming in at the Madrid level by the "fly to" functionality, this geographic area is injected in the *box* query parameter so that only resources restricted to that area are retrieved. While search terms are explicitly typed by users, spatial-based search criteria are automatically bound to the current zoom level (visible geographic area) in the Earth View (Fig. 8).

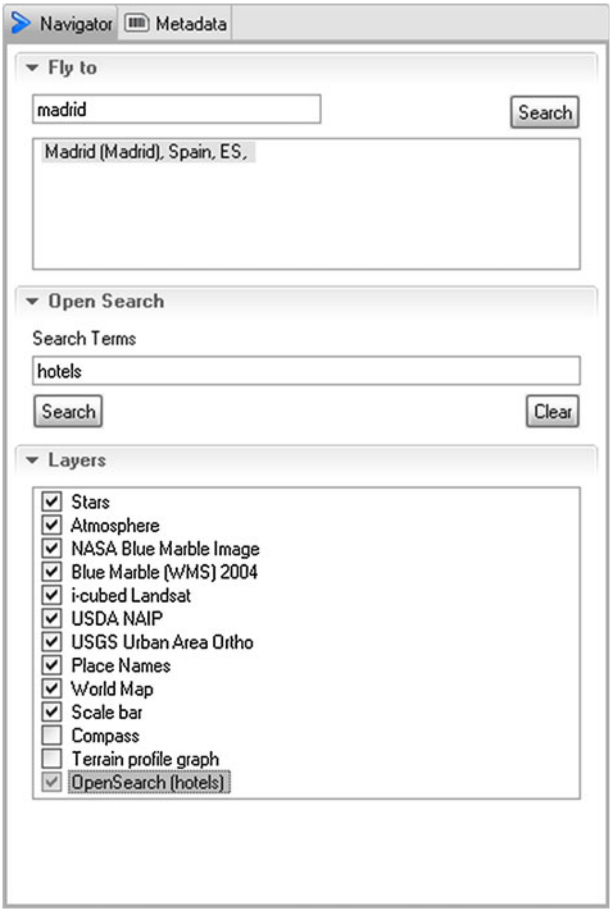

Fig. 7 Screenshot of the navigator view. In the top part the geocoding service. In the middle part the OpenSearch query interface. In the bottom part the list of layers available

As in the case of the geo-coding service, the OpenSearch component is also a client application that takes a user query and gets the resulting resource collection already encoded in the MIMEXT format. Rather than relying on external or third-party services, we have developed an OpenSearch Broker component [43] (Sect. 4). This broker basically launches the user query to several social networks, integrates the result sets and encodes them into a MIMEXT file, which also includes the annotation tasks (MIME types, etc.) over the result set. So, the OpenSearch client (Fig. 8, left) only captures the user query and forwards the resulting collection to the Metadata and Earth views, as detailed in the next sections. The VisioMIMEXT application at full screen and its different views are shown in Fig. 8.

6.2 Metadata view

The main purpose of the Metadata View is to allow users to inspect the collection of media resource form the MIMENXT perspective. Rather than showing every MIMEXT tag, the view permits the inspection in a tree-based structure of the most relevant tags such as <Name>, <Description> and <ExtendedData>, as well as annotations concerned with geo-

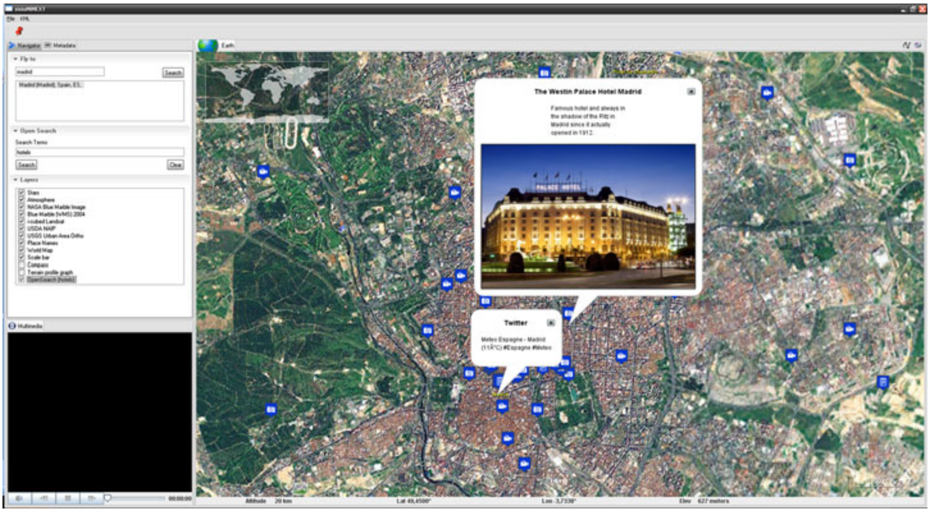

Fig. 8 Screenshot of the main interface. The example shows geo-referenced media resources on the virtual globe retrieved using the search term *hotels* in the Madrid area

referencing and MIME types. All the resources listed in Fig. 9 can be mapped on the virtual globe because both views (Earth and Metadata) are synchronized.

The functionality of the Metadata View is delegated to the File Manager component, which is responsible for processing (parsing) and interpreting KML and MIMEXT files.

Parsing methods read the incoming search results and interpret the structure and semantics of the MIMEXT tags. After studying some KML parsing options, JAK (Java API for KML) [33]

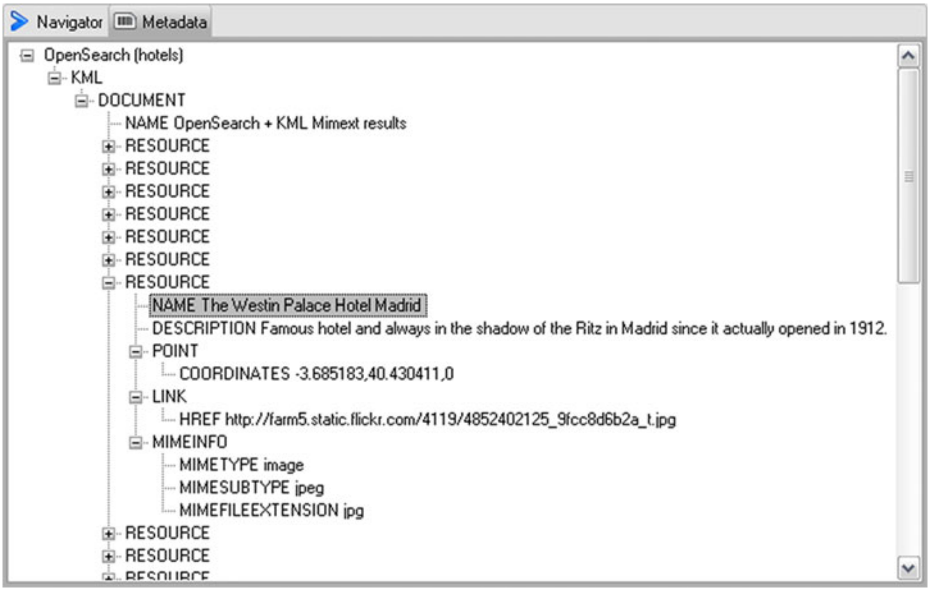

Fig. 9 Screenshot of the metadata view. The example shows the retrieved resources in MIMEXT format in a tree-based format for inspecting their elements and tags

was the parsing library of choice. In contrast to the popular libKML library [38], JAK offers a full implementation of the KML standard and also supports extensibility, which makes it suitable for implementing parsers for KML extensions like MIMEXT.

The File Manager can also compress/uncompress KMZ files and load their content on the virtual globe. Conversely, a MIMEXT file may be compressed for sharing and exchanging a collection of media resources in just one file.

6.3 Earth view

To tackle visualization and multimedia issues, the VisioMIMEXT tool provides the Earth and Media Views. The former provides a 3D model of the Earth and displays most of the media resources. The latter is a specialized view for reproducing certain types of media content that cannot be viewed directly on the virtual globe.

Figure 10 shows the Earth View. It relies mainly on the Drawing Manager for visualization tasks (Fig. 6, right). Regarding the graphical aspects, we use a Java-based virtual globe called NASA World Wind Java (WWJ) [62]. This tool manages the virtual globe itself and the layers we overlap on top of it. All of the KML elements might be potentially displayed on the virtual globe, however only those that refer to resources –KML <Placemark> and MIMEXT <Resource> tags—are implemented and consequently displayed as well as the potential resources included in the KML <Document> and <Folder> KML containers tags.

Fig. 10 Screenshot of the Earth view. The example shows different geo-referenced multimedia resources on the virtual globe

For instance, the Metadata View in Fig. 9 shows the list of <Resources> tags nested in the <Document> container.

The geographic representation of these KML tags is based on the geo-referencing annotation. This information contains both geometry like points and polygons and also related resources such as icons used to visually identify the type of resource. Figure 10 for instance shows two different icons associated to audio and photo resources.

We encountered some limitations in the way WWJ's geometric methods transform descriptive KML geometries (<Point>, <Line>, <Polygon> and <LinearRing>) into their counterpart graphical forms. WWJ is based on OpenGL primitives [63] for rendering geometric representation on the globe. The main issue was that neither WWJ nor OpenGL did not support natively KML format, which means that there was no direct equivalence between KML geometries and OpenGL geometries primitives.

We addressed this issue by extending the WWJ tool with KML (and MIMEXT) support. In doing so, we were able to interpret KML geometry, transform it into OpenGL primitives, and finally display the results on the virtual globe. In particular, we rely on the JOGL (Java bindings for OpenGL) [36] which allows us to adapt any source geometry to the target OpenGL geometric primitives. For instance a KML <LinearRing> tag can be represented in OpenGL as a line with the same first and last point.

The Drawing Manager component also manages the graphical representation of the type of the media resources. For instance, a video resource uses an icon different from a photo resource (Fig. 10). This is usually known as annotations in WWJ or balloons in Google Earth. Here, the term WWJ annotations would refer to balloons[3] normally used for representing, customizing or categorizing a resource on the virtual globe. WWJ balloons support the visualization of certain media types such as text, although more complex media types like video and audio are not supported. For this reason, the Drawing Manager also includes a set of classes (called Balloons Mgmt in Fig. 6), whose aim is to extend the source balloons defined in WWJ and permit the representation of the different geo-referenced media resources on the virtual globe, depending on their nature or type. For example, we have different extended balloons for audio and image resources: audio annotations integrate a simple player to reproduce the resource and the image annotations can show the image itself (Fig. 10).

By clicking on a given icon, a balloon is opened and the selected media resource is shown or reproduced in the case of an audio file. However, some media types entail additional complexity which makes it hard to visualize the resource within the balloon. In these cases, we have designed the Media View.

6.4 Media view

The Media View module plays all content that, for technical reasons, cannot be reproduced directly on the virtual globe; we are particularly referring to video resources. The problem comes from the inherent limitations in OpenGL scenes. As WWJ is based on this graphic library, any element displayed on the virtual globe must adhere to the OpenGL constraints, which unavoidably impedes the proper reproduction of video content [59, 63].

The Media View is thus suggested as a workaround. The balloons for video resources includes buttons that allow users to control the reproduction, yet the reproduction of the video content takes place in a separate view different from the Earth View. Figure 11 shows

[3] We hereafter use the term *balloon* rather than WWJ annotation to avoid confusion.

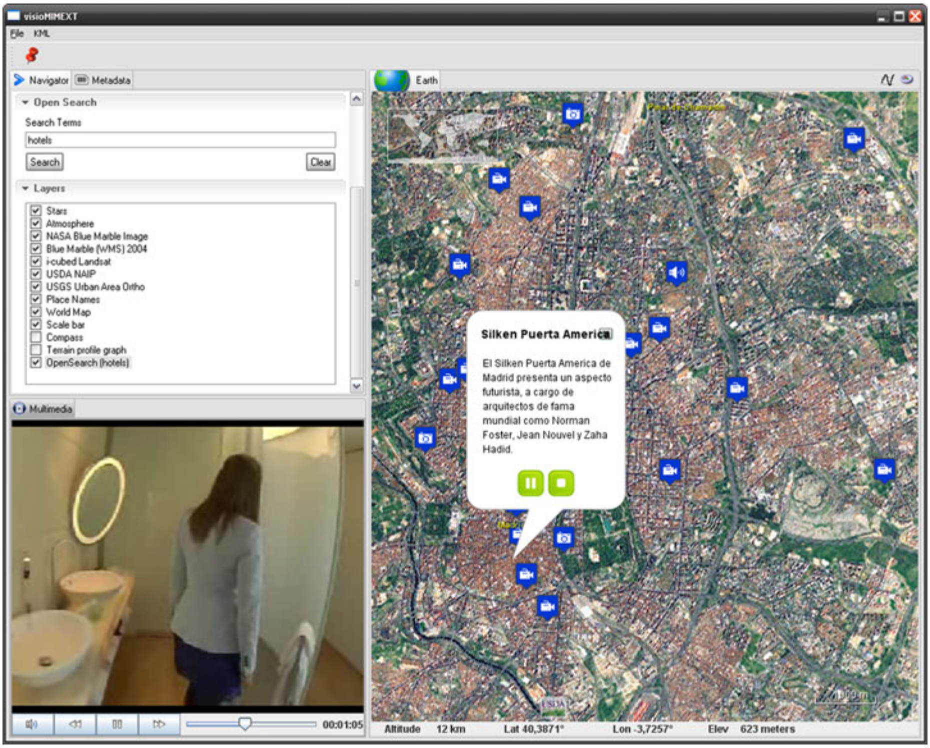

Fig. 11 Screenshot of the media view. The example is playing a video resource

the Media View in the left-bottom corner (depicted as "Multimedia" tab in the figure), while the control buttons are tied to the corresponding geo-referenced balloon.

As in the Earth View, the Drawing Manager component also manages the video content in the Media View. This component contains the needed multimedia library for video management and playback. Specifically, we used the open source GStreamer library [27] that supports a multitude of video formats.

7 Conclusion and future research directions

In this paper, we have presented the VisioMIMEXT application as a proof of concept tool that integrates OpenSearch search interfaces MIMEXT extension language for media annotation, and a set of components to enable searching and the presentation of different types of geo-referenced media resources on a virtual globe.

On the one hand, OpenSearch is a simple but standard method to search for informational resources available online. The benefit of OpenSearch is that it provides a common search mechanism for issuing HTTP-based queries, while being flexible enough to adapt to web resources of diverse nature. By keeping a basic but well–defined search interface it fosters uncoupling between clients and services that enhances greatly scalability.

On the other hand, the MIMEXT extension language allows geo-referencing heterogeneous media resources without depending on their data type or format. MIMEXT does not modify the internal structure of the media formats of the contained resources, since it is based on external annotation techniques. This permits that both current and future resource formats may be described in MIMEXT. Nevertheless, the proposed extension represents a simple solution and does not involve the creation of a new description language to handle diverse types of media formats. In fact, the MIMEXT extension is driven by the application of the principle of reusability whenever possible,-and takes into account certain aspects such as interoperability with other technologies and standards, ease of use, and the degree of assimilation by academia, industry and users in general.

The proposed application demonstrates how OpenSearch search interfaces can enhance discoverability of user-generated content, that is, users are able to find related resources using a spatial-based, uniform query over disconnected social networks and services. Complemented with MIMEXT extension, search results are enriched with mime types aspects and geographic position. Additionally, browsing media resources through a virtual globe user interface become easier and more intuitive to users as search and presentation mechanisms are smoothly integrated in the virtual globe itself. For instance, users can perform more accurate searches considering the current area displayed or determining its precise location.

Our future plans include augmenting the spectrum of search criteria to harness the power of OpenSearch. Time and semantic dimensions should be considered at request time in order to consider media content restricted to a certain time period and specific taxonomy terms. It is critical for the next VisioMIMEXT release to manage the accuracy of the search response, so that the system is able to identify to a certain extent false search positives.

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